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ARTSN: Prototype for an Automated Real-Time Spacecraft Navigation System

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Abstract

ARTSN, the **A**utomated **R**eal-**T**ime **S**pacecraft **N**avigation system, is a prototype of a software system for automated spacecraft navigation and monitoring. It has established a new paradigm for deep space navigation operations by introducing these new capabilities to the deep space navigation analyst:

- *Real-time monitoring of spacecraft and DSN performance through radio metric data and pre-fit residuals.* This system makes it possible for the navigation operations analyst to respond in near-real-time to anomalies, when problem identification is most effective.
- *Automated radio metric data validation and correction.* Up to now all deep space radio metric data required manual validation and correction; this system now can provide that capability for many deep space missions.
- *Real-time orbit and target updates.* Data validation and parameter estimation are data-driven; these tasks are triggered by the receipt of radio metric observables. A real-time orbit solution capability allows for a greater ability to support missions which have a short turn-around between the occurrence of a critical event and the generation of a required response to that event.
- *"One step" access to trajectory, observable, filter, and mapping information.* The traditionally separate functions of trajectory generation, calculation of computed observables, filtering, and mapping are integrated into one software "engine." This engine can be queried in real-time (or off-line) by a shell command (or function call) to provide state, partial derivative, or covariance information.

The current ARTSN prototype has four components: a data pre-processor, a shell interface, an engine, and data displays. In real-time use, the data pre-processor receives data encapsulated into 4800 bit blocks by the Deep Space Network (DSN) and creates measurement records from this data. The pre-processor performs data validation checks and corrections to these records, and supplies a time-ordered sequence of Doppler and range data, which can be saved to files for use by the ARTSN engine or the legacy deep space navigation software suite.

The ARTSN shell is a command-line style interactive user interface that translates namelist inputs into engine remote procedure calls. As mentioned earlier, the ARTSN engine is where the integrations, observable computations, filtering, and mappings are performed, separate from the user interfaces; thus, the input and output processes can be modified for specific projects and users without modifying the engine. The engine can be run on any platform which supports an ANSI C compiler, and was designed in an object oriented style.

The displays for this prototype are LabVIEW graphical applications; any package with a TCP/IP network interface can be used to create an ARTSN real-time display. By using remote procedure calls, the displays configure the engine to send the correct data stream back to them without user interaction directly with the engine. Front- and back-end displays can be implemented on relatively inexpensive desktop PCs while the engine runs on a workstation.

To date, there have been end-to-end demonstrations of ARTSN capabilities across several deep space missions. In mid-1997, ARTSN processed the end of Mars Pathfinder interplanetary cruise, displaying post-fit residuals and updated Mars encounter estimates. Later that year, ARTSN displays were used by the Mars Global Surveyor navigation team to observe and make a 'quick-look' assessment of the Mars Orbit Insertion (MOI) maneuver. In early 1998, the NEAR navigation team used the ARTSN pre-processor to assess the line-of-sight component of several spacecraft maneuvers.

ARTSN also serves as a useful tool for research into new navigation algorithms. The engine is being used through function calls to supply spacecraft state vector and partial derivative information to autonomous navigation and maneuver design efforts, and will be used in a demonstration of adaptive interplanetary orbit determination.

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